What CDF Can Say About the Higgs

John Conway
Rutgers University

SUSY 04 - Tsukuba, Japan
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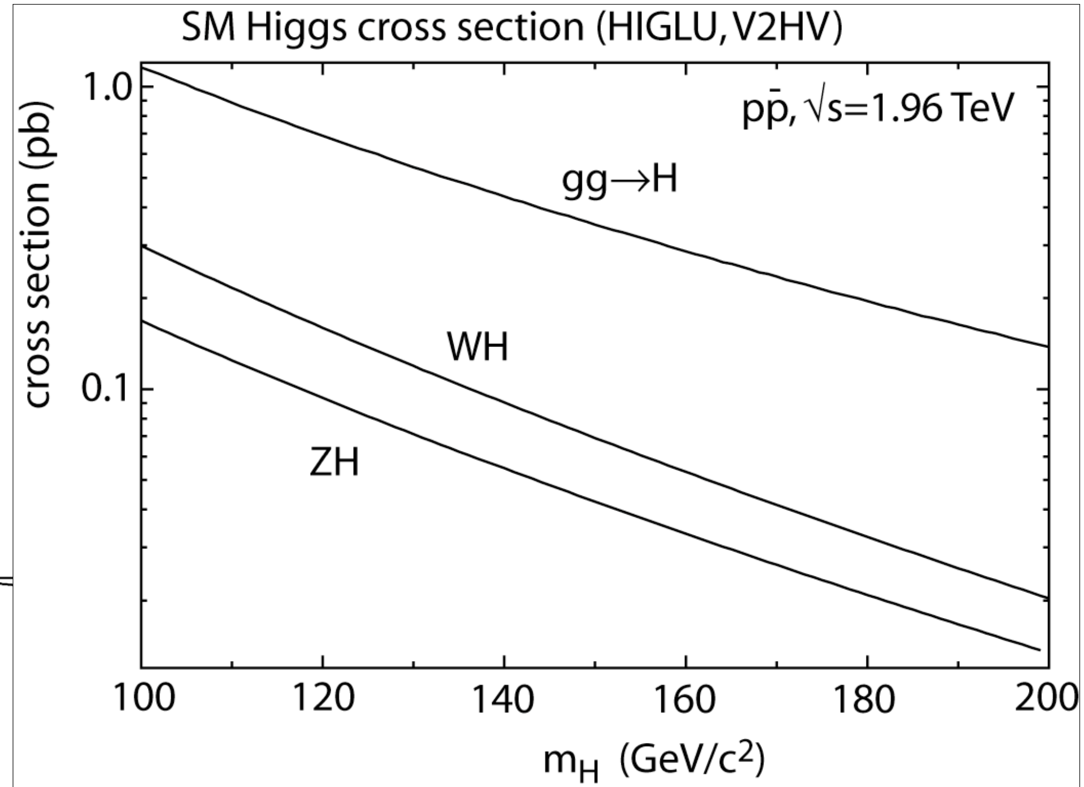
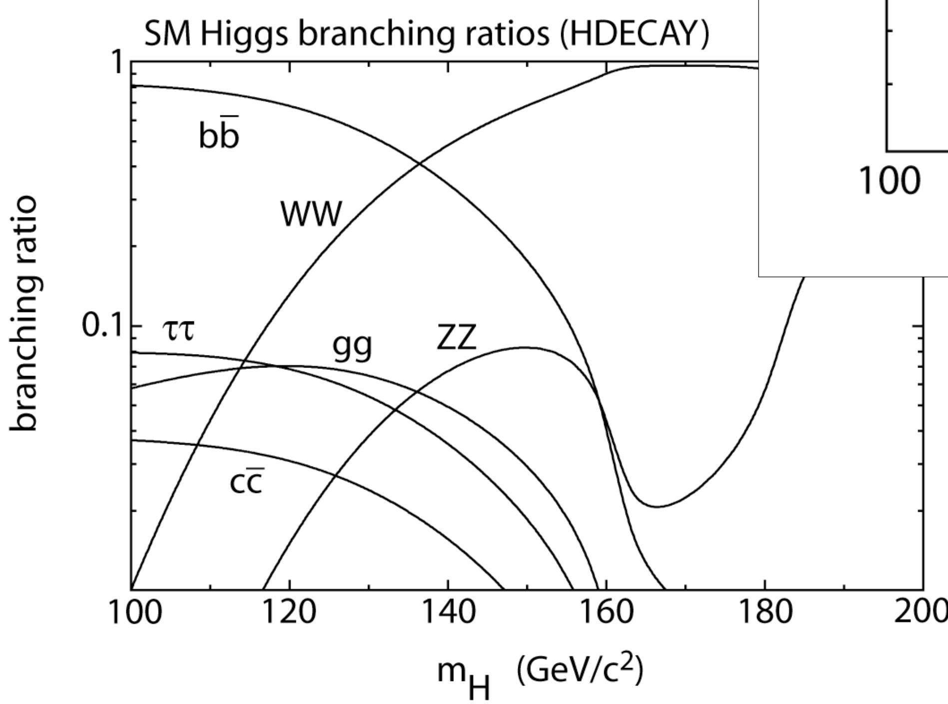
SM Higgs Production

- gg→H dominates but dijet background too big…
- bb and WW decay modes are best!





WH+ZH ~300 fb at 115 GeV

typical efficiencies ~ 2%

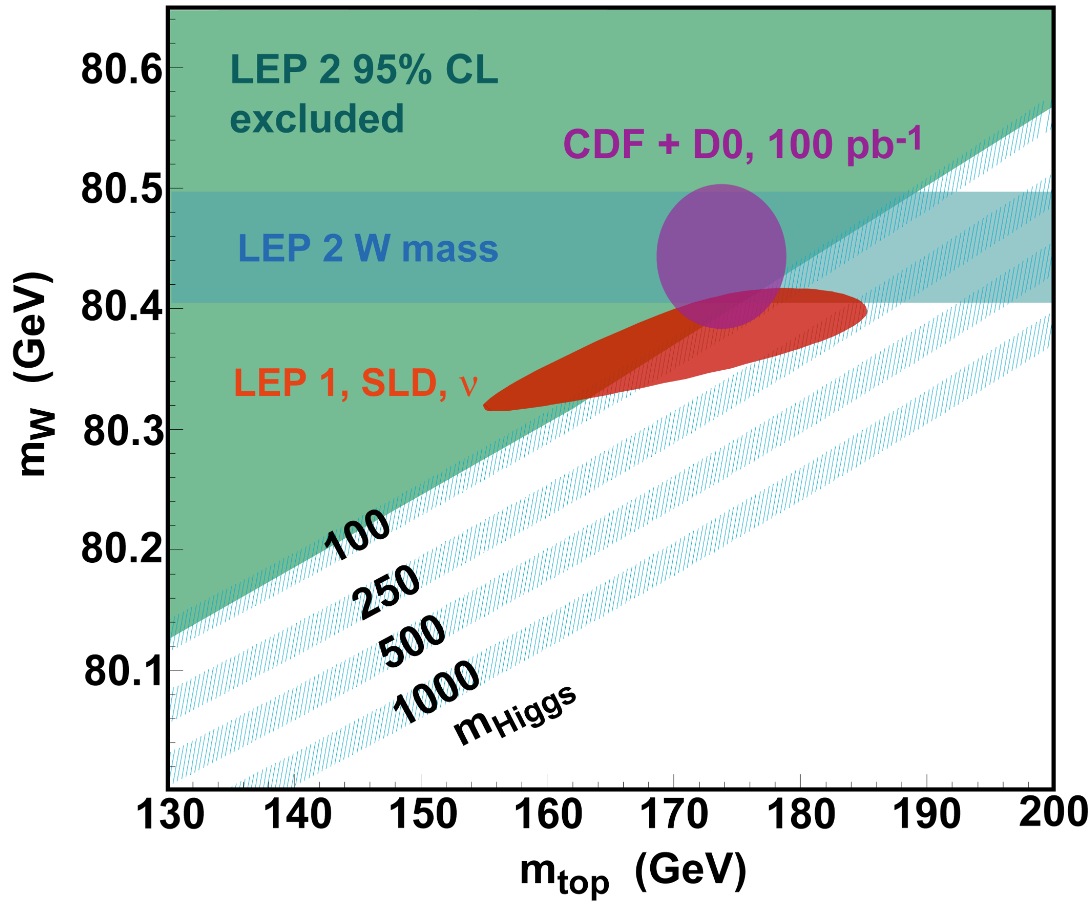
A daunting proposition!

Top and W Masses

- initially at the Tevatron, we focus on measuring the mass of the W and top quark

- tight constraints on Higgs mass

- this is what CDF and D0 do best!

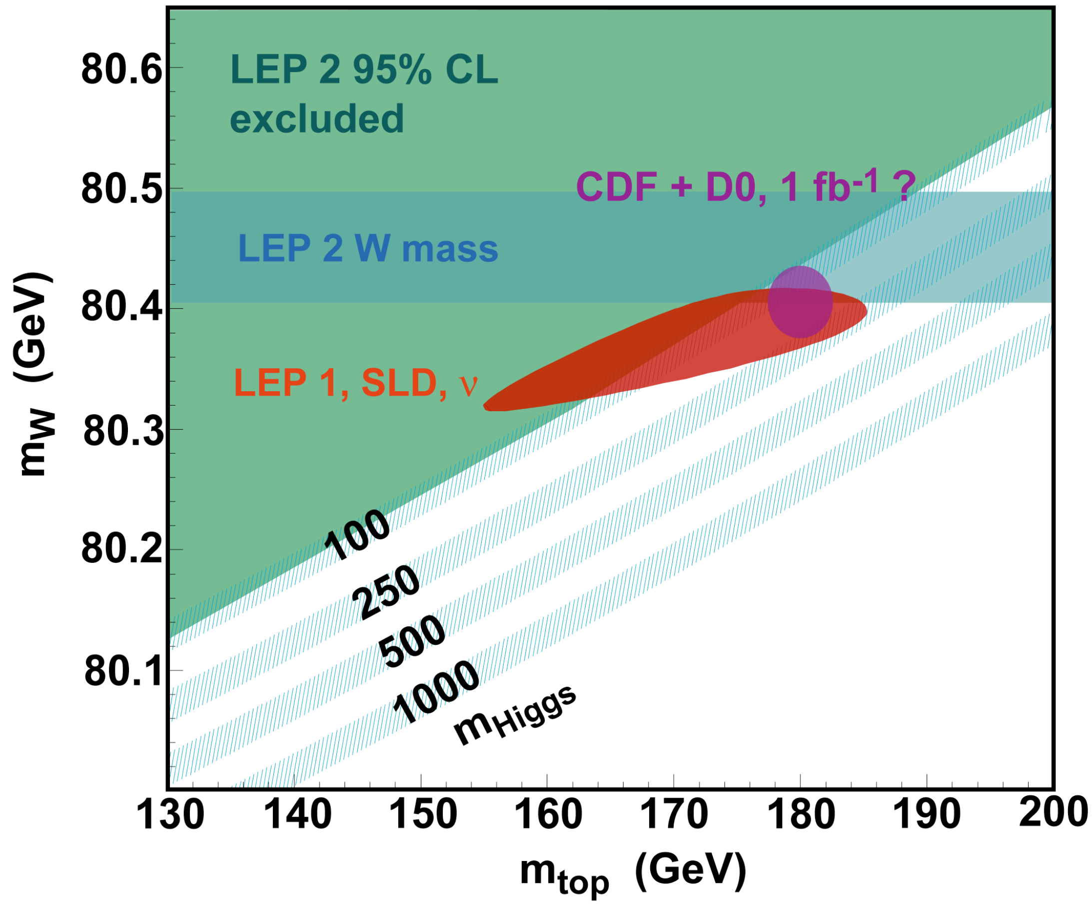


Lots of work to do on b tagging, jet energy reconstruction, mass reconstruction, understanding background…all of which is preparation for the direct Higgs search!

Top and W Masses

Suppose CDF and D0 measure the top and W masses as shown here:

This would be evidence for new physics!

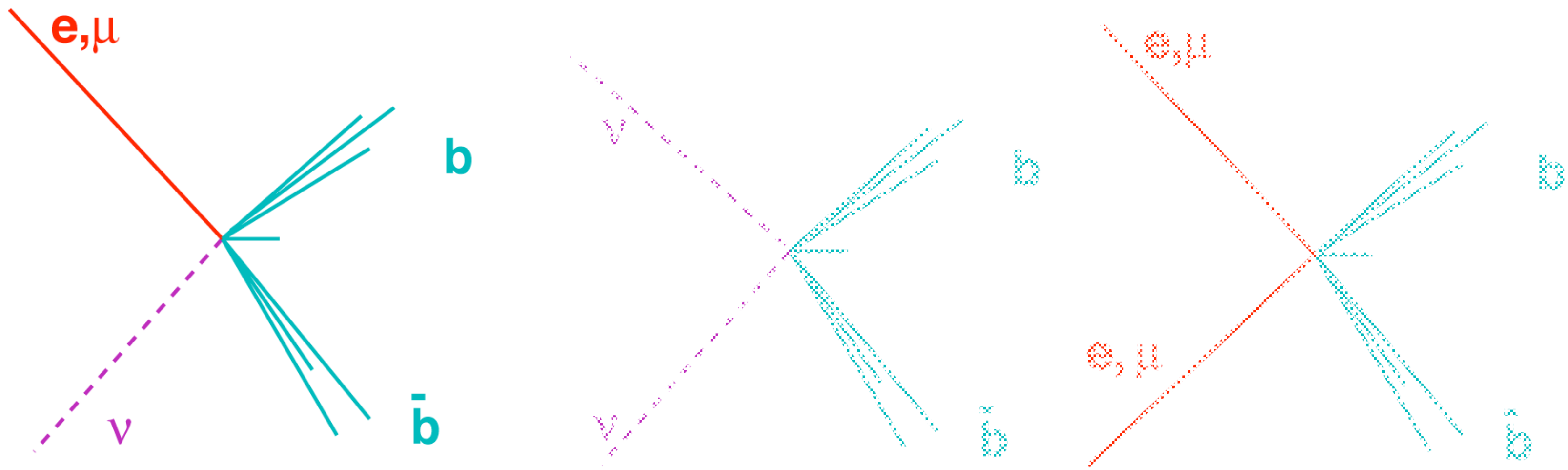


Lots of work to do to get to this point…exciting prospect!

Or maybe it won't be evidence for new physics?

Search Channels - Low Mass

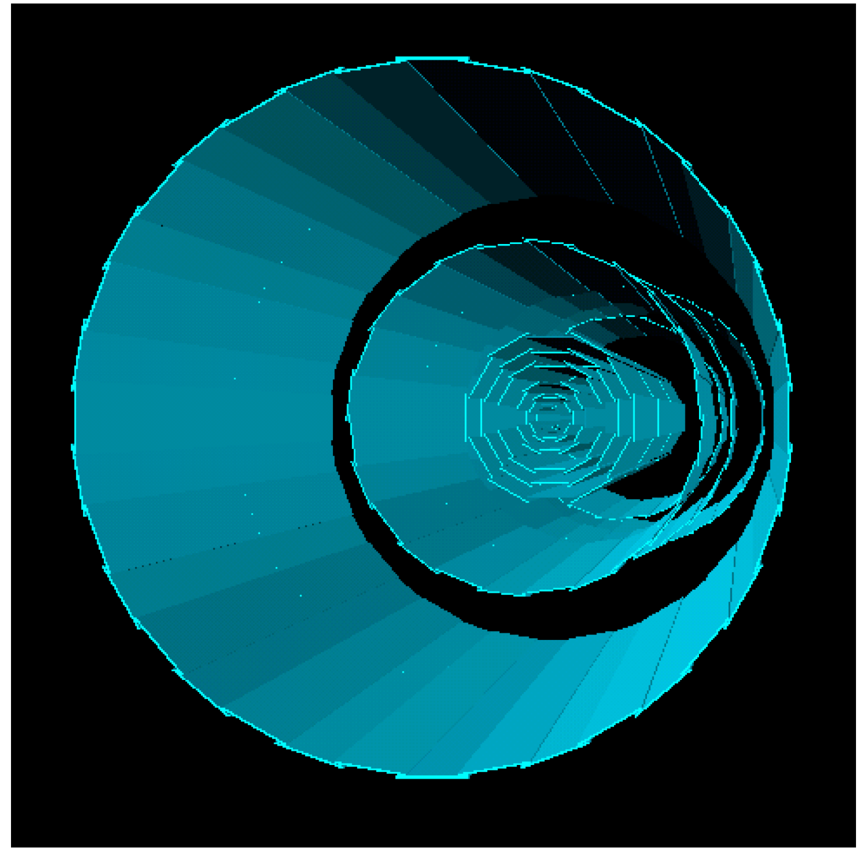
For m_H<135 GeV, bb decays dominate:



WH **ZH**

- clearly need excellent b tagging
- need optimal bb mass resolution
- need to understand background shapes

CDF - b tagging



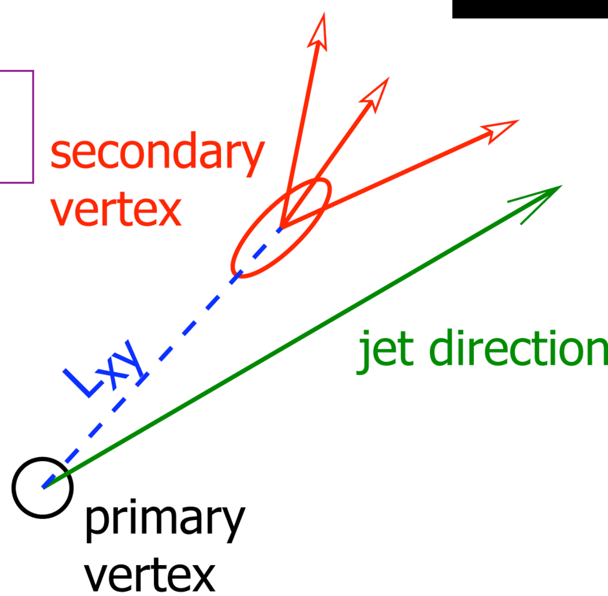
Layer 00, SVX-2 and ISL

Double-sided silicon microstrips: 800k channels

r ~1.5 cm out to ~50 cm

Extrapolation resolution:

10~15 μm



ε_b ~ 53% (top)

ε_c~3% $\varepsilon_{q/g}$<1%

Run 2 $\ell\nu$bb Result

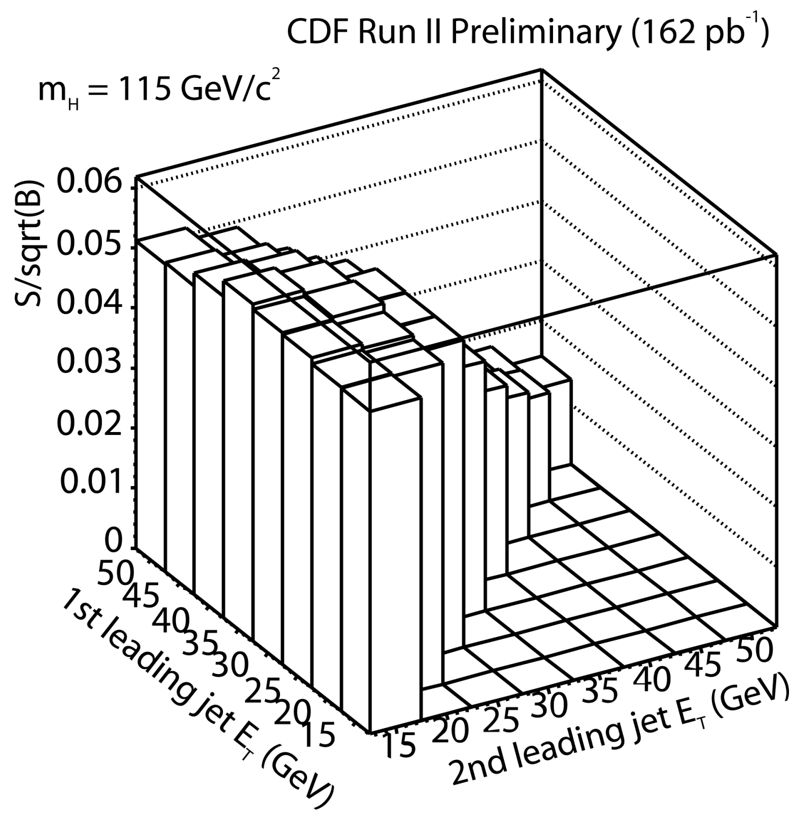
- Select events with p_T>20 GeV lepton triggers
- Require lepton, missing E_T, two jets with E_T> 15 GeV
- Demand at least one b-tagged jet

Very similar to top lepton plus jets selection

Acceptance ~1.7%

Main backgrounds: Wbb, fakes

(thesis of Y. Ishizawa, Tsukuba)



Run 2 $\ell\nu$bb Result

Comparison of observed/expected:

Background	$W^{\pm}+1$ jet	$W^{\pm}+2$ jets	$W^{\pm}+3$ jets	$W^{\pm}+\geq 4$ jets
Events before tagging	13417	2072	313	82
mistags	36.20 ± 5.40	14.07 ± 2.10	3.97 ± 0.68	2.04 ± 0.39
$W^{\pm}+b\bar{b}$	18.58 ± 4.82	12.05 ± 2.19	2.82 ± 0.57	0.99 ± 0.25
$W^{\pm}+c\bar{c}$	9.44 ± 2.94	5.19 ± 1.14	1.04 ± 0.25	0.35 ± 0.11
$W^{\pm}+c$	33.08 ± 7.83	7.86 ± 2.08	1.36 ± 0.39	0.28 ± 0.10
Diboson/$Z^0 \rightarrow \tau^+\tau-$	1.74 ± 0.30	2.25 ± 0.34	0.59 ± 0.13	0.10 ± 0.03
QCD	22.34 ± 2.69	10.31 ± 1.66	2.44 ± 0.57	0.56 ± 0.18
$t\bar{t}$	0.42 ± 0.07	5.05 ± 0.64	12.65 ± 1.57	20.10 ± 2.49
single top	1.14 ± 0.15	3.76 ± 0.49	0.90 ± 0.12	0.17 ± 0.03
Total Background	122.84 ± 11.40	60.55 ± 4.43	25.77 ± 2.16	34.62 ± 2.59
Observed positive tags	135	62	23	21

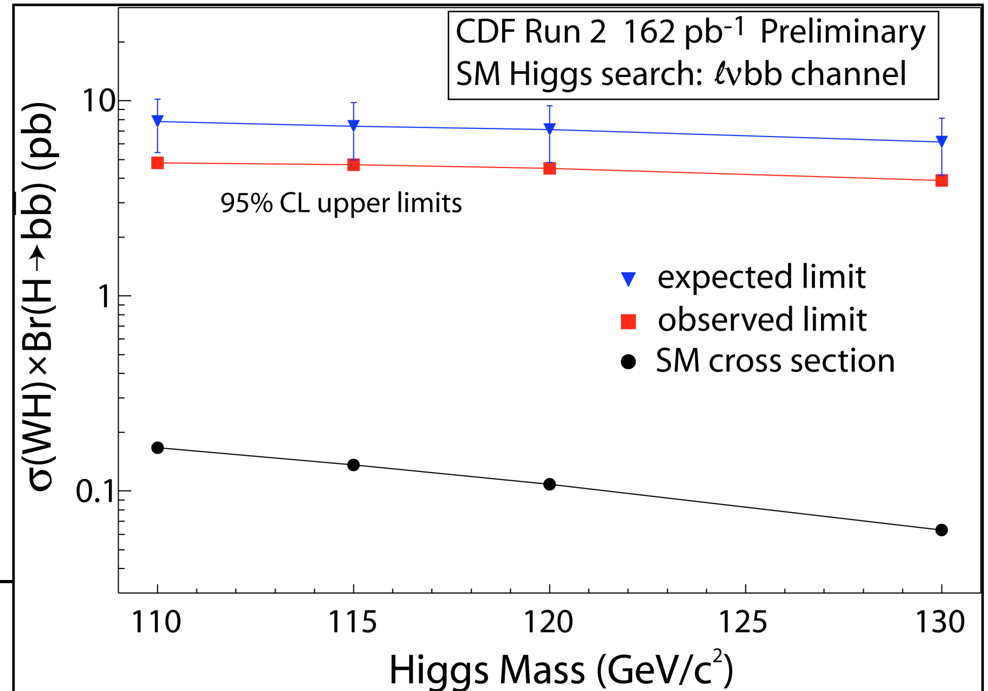
Higgs search

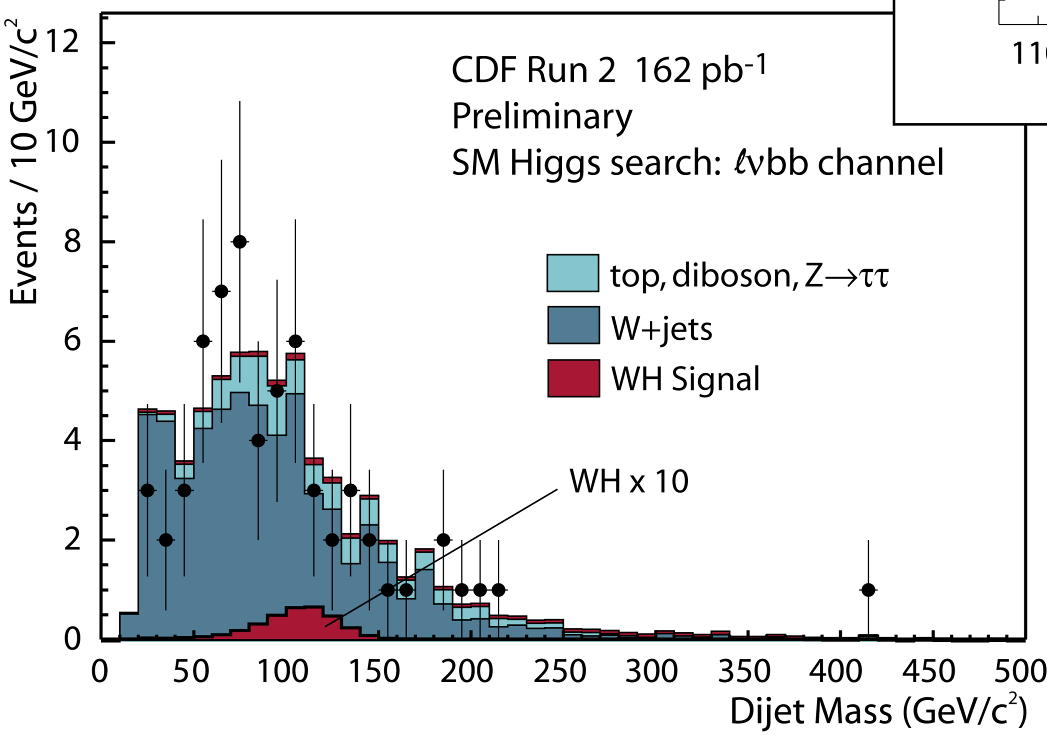
Top cross section

Run 2 ℓνbb Result

Use bb mass distribution for signal sensitivity

~16% resolution so far

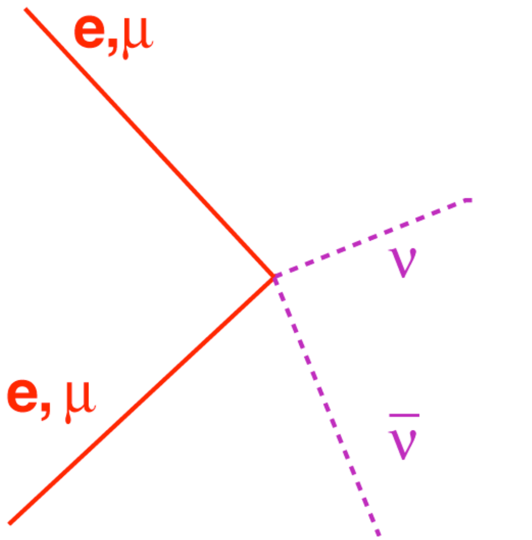




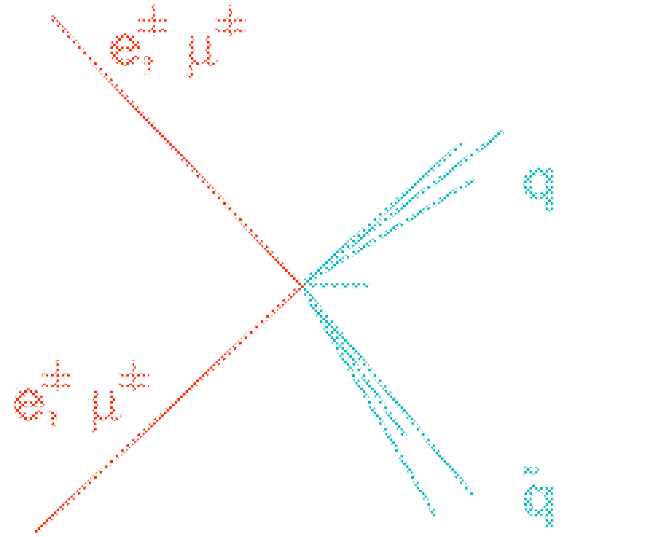
We are not yet challenging the Standard Model:

- better resolution
- improved tagging
- need ννbb channel

Search Channels - High Mass



gg→H→WW →ℓℓνν



ZH/WH→WWW/ZWW

(trileptons: rate too low)

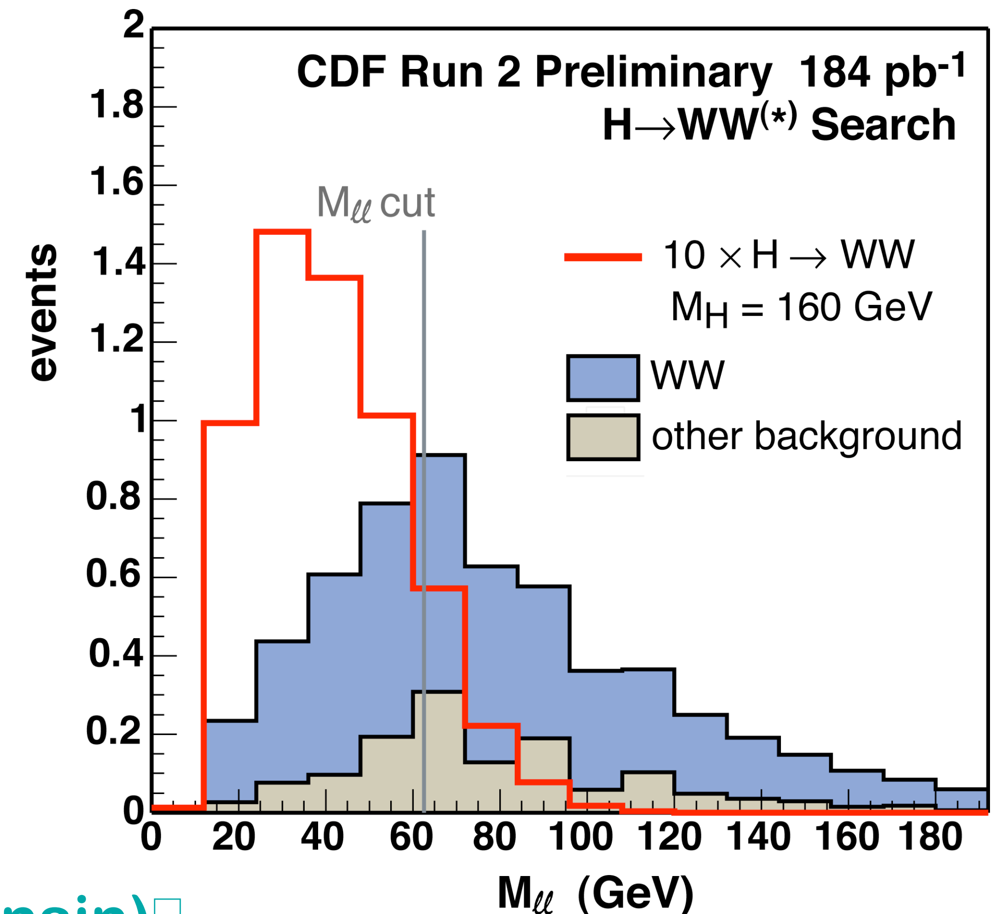
New Run 2 result performed in context of WW analysis

Run 2 $\ell\nu\ell\nu$ Result

Select events with two high-p_T leptons (ee, eμ, $\mu\mu$)

Main background: WW

Use dilepton invariant mass as discriminating variable:



(thesis of S. Chuang, Wisconsin)

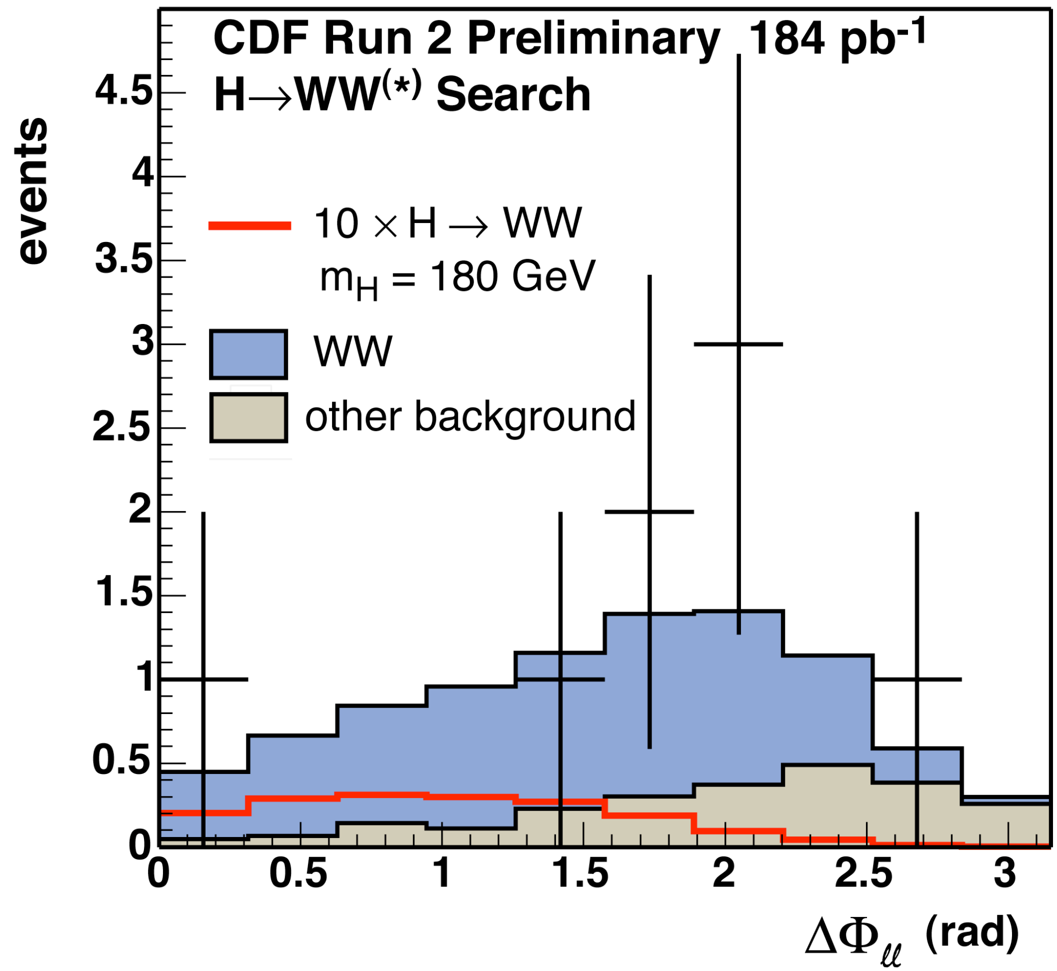
Run 2 $\ell\nu\ell\nu$ Result

M_H assumed	140 GeV	150 GeV	160 GeV	170 GeV	180 GeV
M_{ll} cut (GeV)	55.0	57.5	62.5	70.0	80.0
DY ee	0.0000±0.0000	0.1501±0.1569	0.4201±0.2756	0.7202±0.3912	0.8703±0.4448
DY $\mu\mu$	0.1676±0.1073	0.1676±0.1073	0.2160±0.1217	0.3229±0.1576	0.4270±0.1878
DY tt	0.0052±0.0027	0.0074±0.0033	0.0140±0.0052	0.0219±0.0074	0.0263±0.0082
ttbar	0.0083±0.0052	0.0083±0.0052	0.0083±0.0052	0.0111±0.0061	0.0172±0.0081
ZZ	0.0224±0.0025	0.0252±0.0028	0.0312±0.0032	0.0428±0.0041	0.0639±0.0058
WZ	0.0832±0.0087	0.0963±0.0098	0.1187±0.0115	0.1462±0.0135	0.1844±0.0164
WW	3.5048±0.4099	3.8170±0.4463	4.4496±0.5201	5.3799±0.6285	6.4922±0.7583
fakes	0.3970±0.1225	0.4500±0.1398	0.5300±0.1638	0.6460±0.1946	0.8140±0.2529
total bg	4.1885±0.4495	4.7219±0.5177	5.7878±0.6447	7.2910±0.8146	8.8952±0.9759
HWW	0.1042±0.0122	0.1553±0.0182	0.2241±0.0262	0.2200±0.0258	0.1716±0.0201
S/sqrt(S+B)	0.0503	0.0703	0.0914	0.0803	0.0570
data	2	2	3	7	8

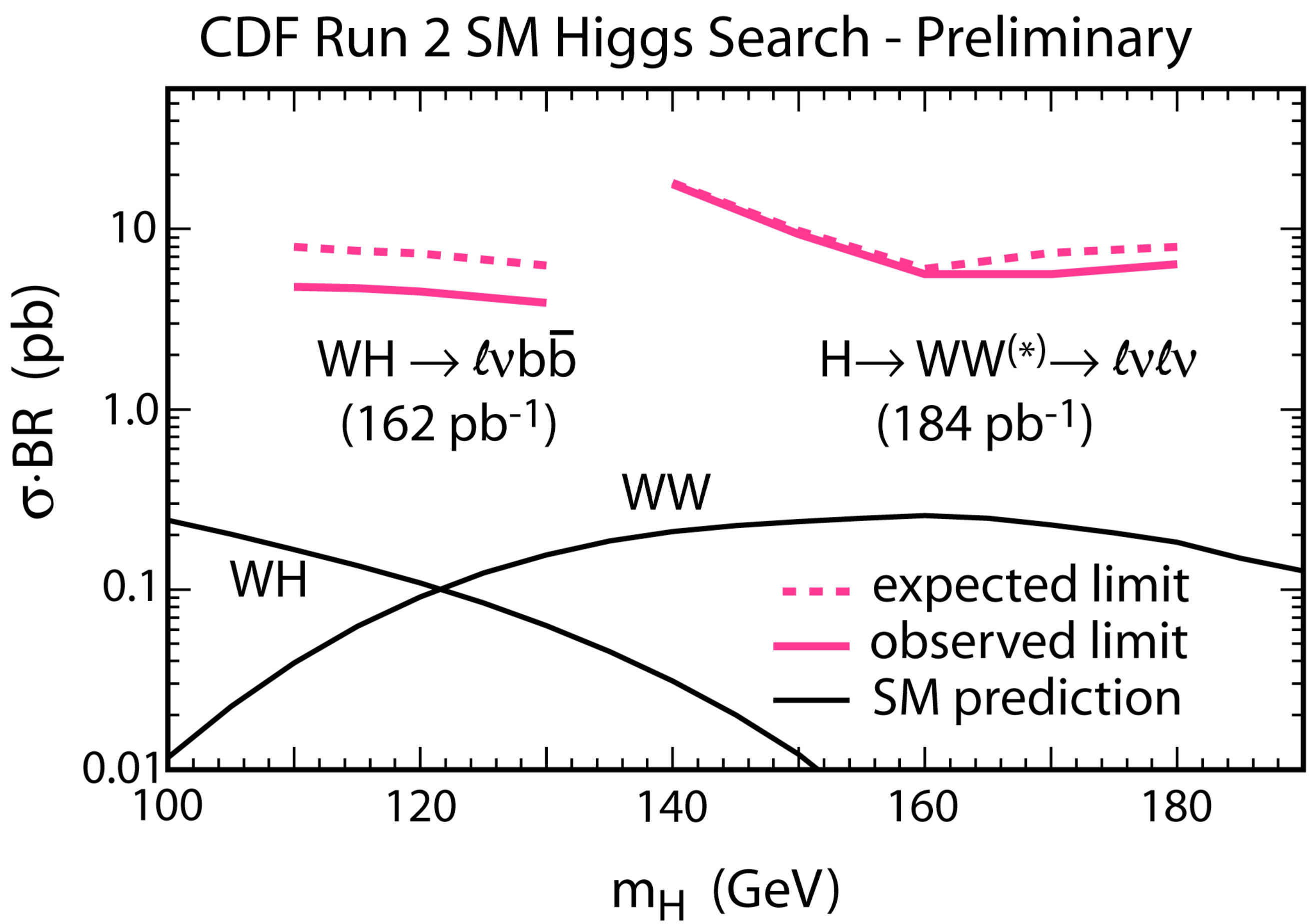
Run 2 $\ell\nu\ell\nu$ Result

Perform likelihood fit using angular distribution

Extract 95% CL upper limit using Bayesian approach



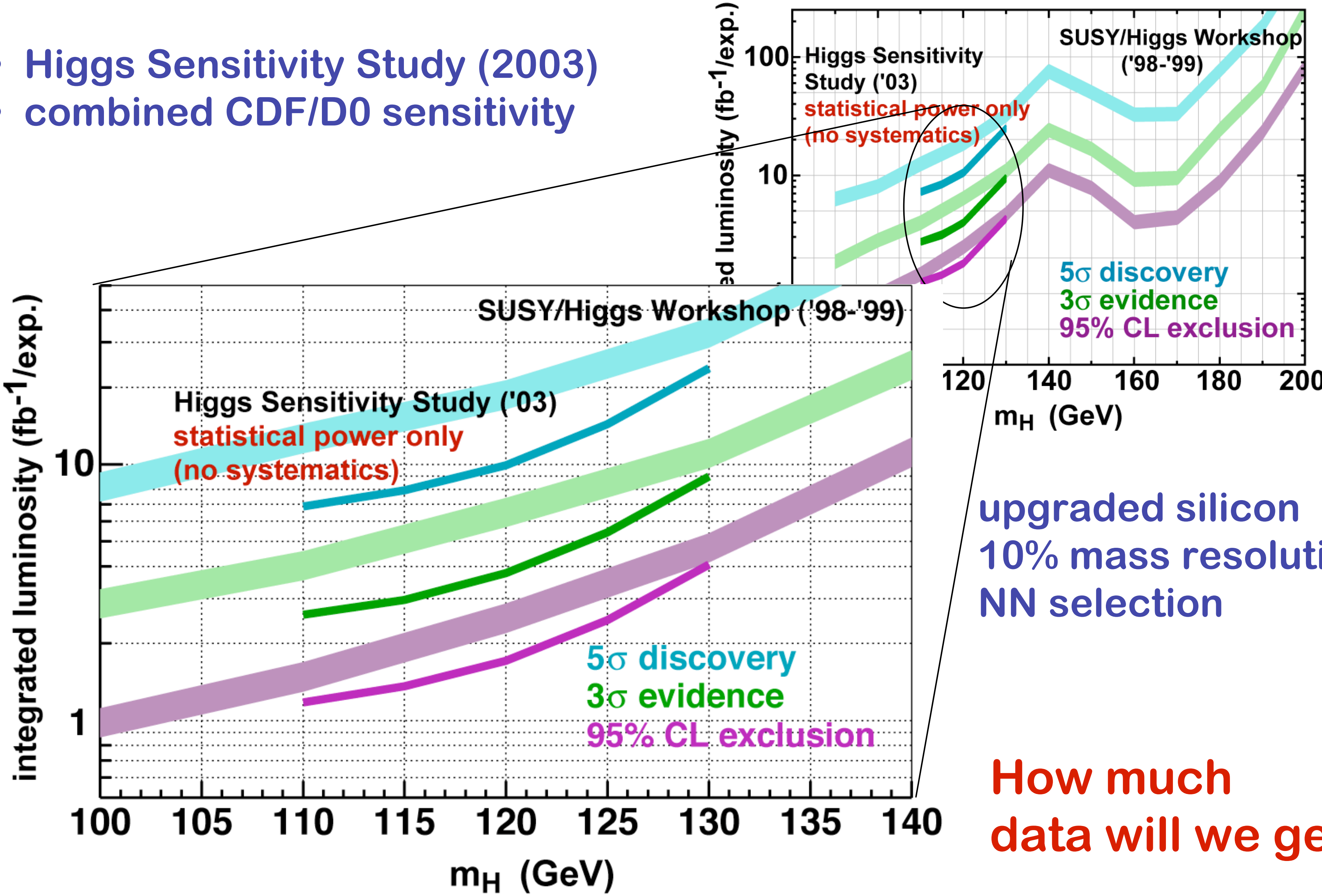
CDF Run 2 SM Higgs limits



We clearly have our work cut out for us…how long will it take?

Revised SM Higgs Reach Estimate

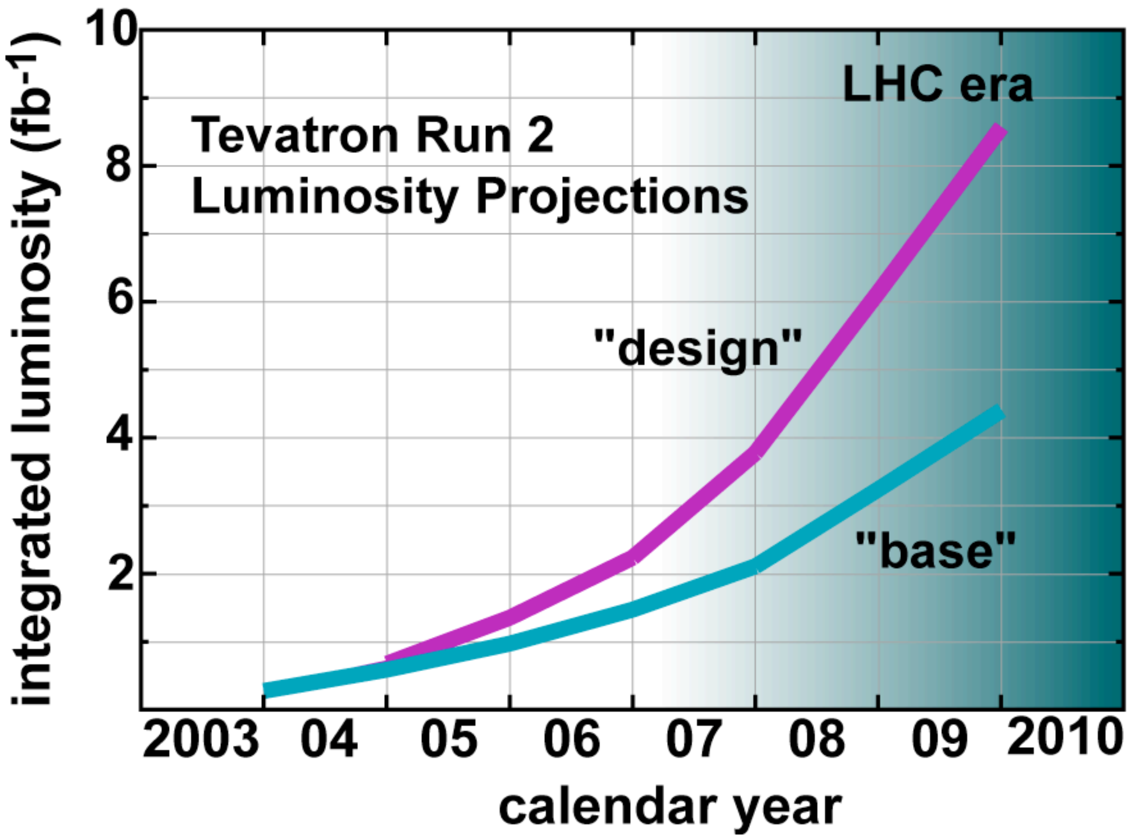
- Higgs Sensitivity Study (2003)
- combined CDF/D0 sensitivity



upgraded silicon
10% mass resolution
NN selection

How much data will we get?

Tevatron Run 2 Projections



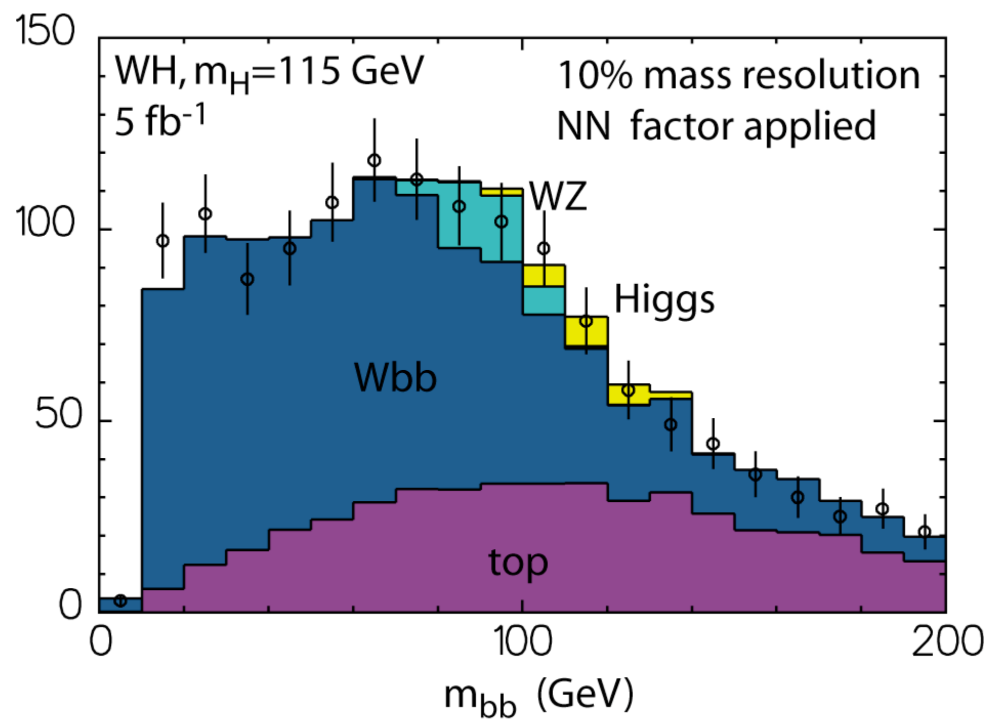
- "design" goal requires electron cooling in Recycler
- Tevatron running well in 2004 - may achieve 10^{32} soon

4-5 fb^{-1} by LHC turn on?

September 2003: Run 2b silicon project cancelled!
This degrades the projected reach substantially…

WH channel

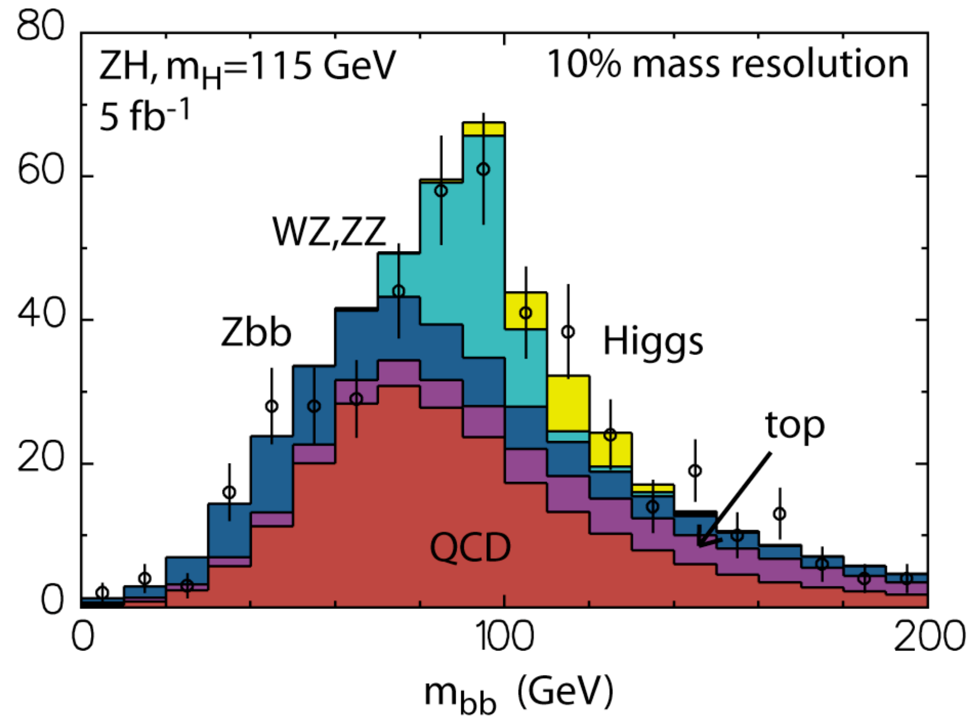
- assume SHW-level b tagging but declining at large eta
- 10% mass resolution
- signal and background scaled by a factor of 1.6 to account for effect of neural network-type selection



To do this channel, need to control background shape very accurately.

ZH channel

- use NN for selection
- incorporate $\ell\ell$bb by scaling signal and background by 1.33
- QCD background from real data!
- sensitivity a bit better than SHW report
- significant acceptance from WH process!



Need to ensure that there is no acceptance overlap with $\ell\nu$bb channel

Is there hope for SM Higgs?

Main impact of Run 2b silicon cancellation: poorer b tag efficiency.

Signal rate ~ ε_b^2 and background is real b jets!

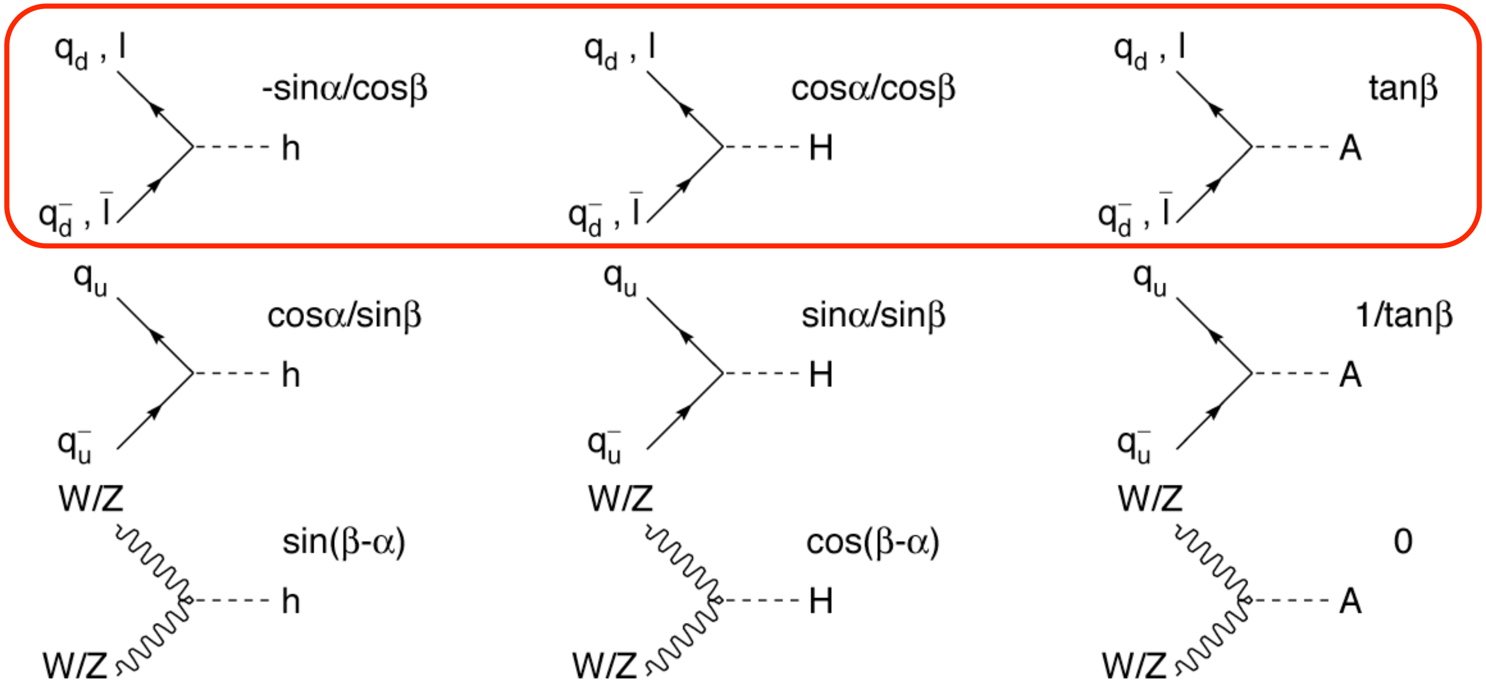
$\Rightarrow L_{req} \sim \varepsilon_b^2$ too!

We are working at an operating point in b tagging where we maximize purity…but is this the right strategy?

Need new, more flexible b tagging algorithms!

I believe we will achieve 95% exclusion limits up to ~120 GeV mass.

MSSM Higgs at the Tevatron

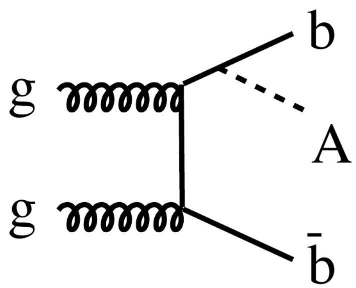


Top row leads to enhanced production at large tanβ

$$\sigma(pp \rightarrow bbH/bbA/bbh) \propto \tan^2\beta$$

"Forward enhancement" ?

Willenbrock et al: enhancement for Higgs+b (hep-ph/0304035, hep-ph/0312024)



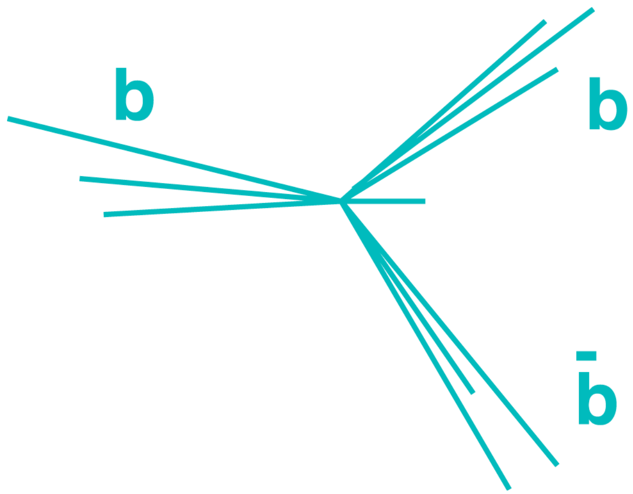
Pole in cross section (related to b structure function) in case where one b goes forward.

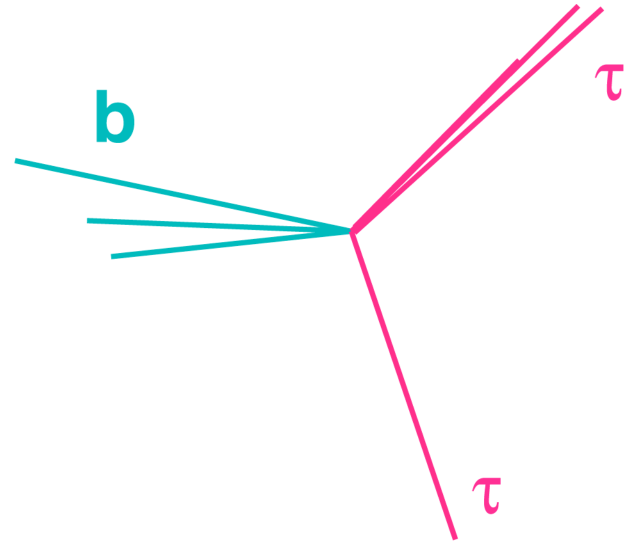
$$\sigma(bA) / \sigma(bbA) = 10\ !$$

Similar enhancement predicted for Z+b !

$$\sigma(Zb) \cdot B(Z \to \ell\ell) = 0.9\ \text{pb}$$

bH/bA/bh → bbb and $\tau\tau b$



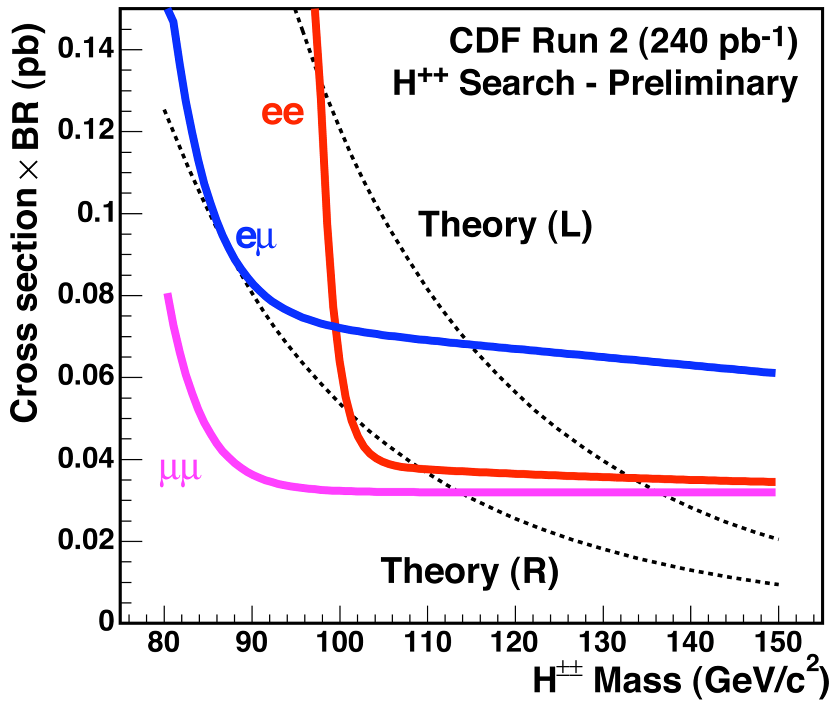


- 90% branching ratio
- difficult to trigger
- don't know which pair
- lots of background

- trigger exists
- can reconstruct mass
- low background (Zb)
- 8% branching ratio

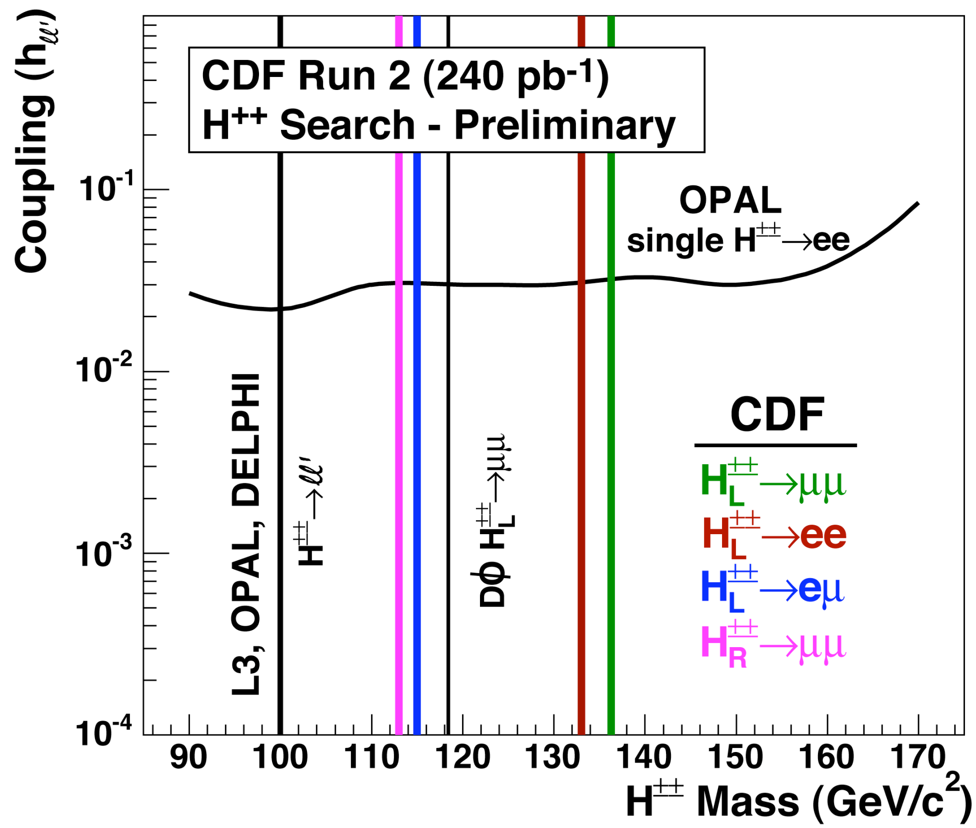
Results coming soon on both of these!

Doubly Charged Higgs



like sign lepton pairs:

- high efficiency
- low background



Search limits in the range of 10's of fb!

Outlook

At the Tevatron we can address key scientific questions before LHC turn-on:

Is there a SM (or SM-like) Higgs up to masses of ~120-125 GeV?

Can we see evidence of high-tanβ-enhanced production of MSSM Higgs?

Is there evidence for other more exotic Higgs species?

It's still exciting and it's great preparation for the LHC!